Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE BOGS AND BOG FLORA OF THE HURON RIVER VALLEY.

EDGAR NELSON TRANSEAU.

(WITH SIXTEEN FIGURES)

I. The Huron River valley.

PHYSIOGRAPHIC FEATURES.

THE Huron River valley, to the botanical survey of which the present paper forms the sixth contribution, is located in the southeastern part of Michigan. As indicated in *fig. 1*, the valley embraces parts of five counties.

Throughout, its surface forms are of glacial origin and, with the exception of the immediate borders of the river, have undergone but slight modification since glacial times. Perhaps its most striking topographic features are the rough morainic hills of its upper and middle courses, and the gently undulating plain of its lower course.

The river has its source in west-central Oakland County in Big Lake, 9 miles (14.5^{km}) southeast of Holly and approximately 40 miles (64^{km}) northwest of Detroit. Starting with an elevation of 950 feet (290^{m}), after a course, extending for 50 miles (80^{km}) generally southwestward and then for another 50 miles (80^{km}) southeastward, it empties into Lake Erie at an altitude of 573 feet (175^{m}) above tide. As is common in areas of glacial deposition, the topography of the drainage basin of the Huron has little of the appearance usually suggested by the term "valley." The upper two-thirds of its course is a winding depression among morainic knobs, lake basins, abandoned glacial drainage channels, and sand plains. Here the river is characterized by long reaches and occasional slight riffles. At intervals it broadens into stretches of lake-like character, as is illustrated by such bodies of water as Commerce, Taylor, Strawberry, Whitewood, and Bass Lakes, each with an area of one-fourth to one-half a square mile (65–130 hectares). The river margin is usually low and swampy.

Its tributaries enter it at every angle, and bring to it the drainage of hundreds of lakes and swamps. Most of these lakes are small, occupying areas of an acre (half a hectare) or more, but there are several of considerable size. Portage and Whitmore[1] Lakes occupy one and one-fourth to one and one-half square miles (325–390 hectares), while Union, Straits, Four-Mile, Ore, Independence, etc., cover a fourth to half a square mile (65–130 hectares). A very large percentage of the tributaries lie in flat-bottomed depressions whose surface approximates the ground-water level, consequently producing thousands of acres of swamp and marsh land. Everywhere occur small undrained depressions, some well above the average ground-water level, others containing lakes and bogs. It is also worthy of

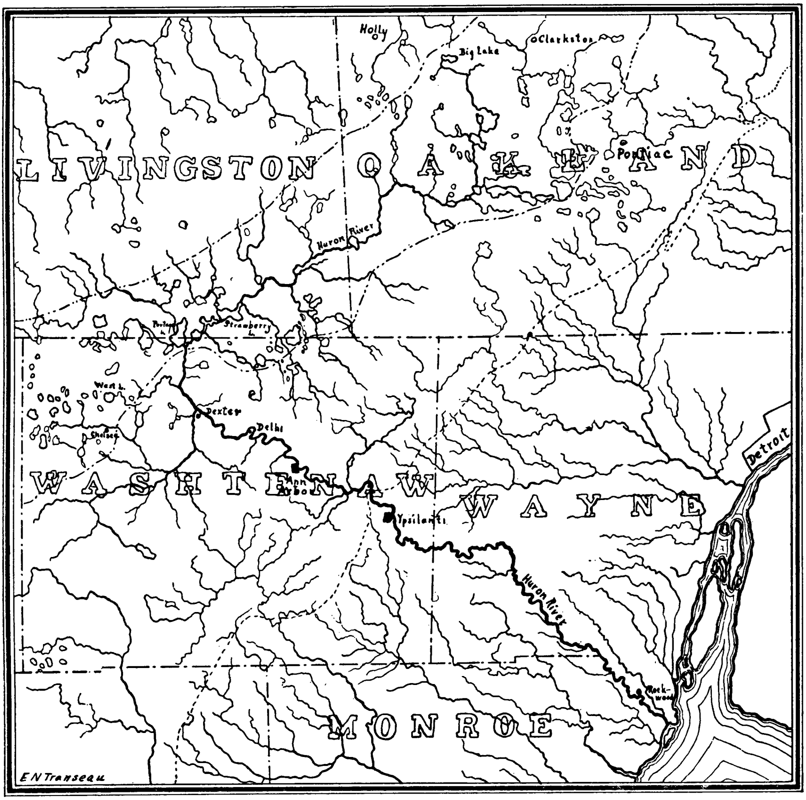


FIG. 1.—Map of the Huron drainage basin. The boundaries of the interlobate moraine are shown by the lines —·—. The boundary between the clay morainic belt and the lake plain is marked by the line - - - - -.

---

[1] Not connected with the Huron River by surface drainage.

note that a large part of the surface drained by the Huron and its tributaries, before it makes the great bend to the southeast below Portage lake, is made up of sand and gravel, composing and accompanying the Saginaw-Erie interlobate moraine. It is a region of steep hills, with occasional dry plains, everywhere penetrated by lakes and swamps.

The country which the river next crosses, beyond the great bend, for a distance of 20 miles (32^{km}) is composed of glacial till plains and clay moraines—a belt extending NE-SW, approximately parallel to the interlobate moraine. Here, although the hills are well marked, the slopes are more gradual and the basins broader. The river is bordered by banks several feet in height, and seldom attains a width of 150 feet (50^{m}).

The last 30 miles (50^{km}) of the Huron River traverses a meandering course sunken from 50 feet (15^{m}) at Ypsilanti to 25 feet (7.5^{m}) at Rockwood below the surface of a glacial lake plain sloping gently southeastward from the morainic belt just described, to the western shore of Lake Erie. The soil is here composed of sand, sandy loam, and—in the vicinity of the lake—clay; the only topographic features aside from the sunken water courses being the several beach ridges and dunes marking the successive stages in the lowering of the glacial lakes, forerunners of the present Lake Erie.

There are, then, three natural divisions of the Huron drainage basin: (1) the loose-textured rough interlobate moraine; (2) the clay morainic belt lying to the southeast of it; (3) and the low-lying plain extending to Lake Erie. Each implies important differences in the way of bog formation and provides edaphic factors which determine to a large extent the nature of the dominant forest covering.

PHYSIOGRAPHIC HISTORY.

The history of these topographic features is for the most part bound up with the retreat of the ice at the close of the last (Wisconsin) glacial epoch. A topographic map of the region lying between Lakes Michigan and Erie shows that the morainic hills so characteristic of the Huron basin are part of a belt of similar physiography extending from northern Indiana well up into the "thumb" of lower Michigan (*fig. 2*). This belt of glacial deposits is directly connected with the development of reentrant angles along its crest, as the great continental ice sheet[2] became more and more differentiated into lobes during its retreat (**52, 13**). In northern Indiana it marks the first areas uncovered, as the mass of ice, pushed forward from the basin of Lake Michigan, separated from that originating in the Lake Huron and Lake Erie basins.

When the Huron River basin was reached, the Saginaw lobe had been developed and lay over the northwestern part, while the Huron-Erie lobe covered all of the territory southeast of the interlobate moraine. The first portion of our area to be uncovered is the triangular gravel outwash apron extending southwestward from Sugarloaf Knob. This was the beginning of the Huron River. Kavanaugh Lake then lay just under the edge of the Erie ice, and Crooked Lake occupied a similar position on the southern border of the Saginaw lobe. As has been recently determined by Mr. FRANK LEVERETT, of the U. S. Geological Survey, the subsequent history of the Huron drainage is most remarkable.

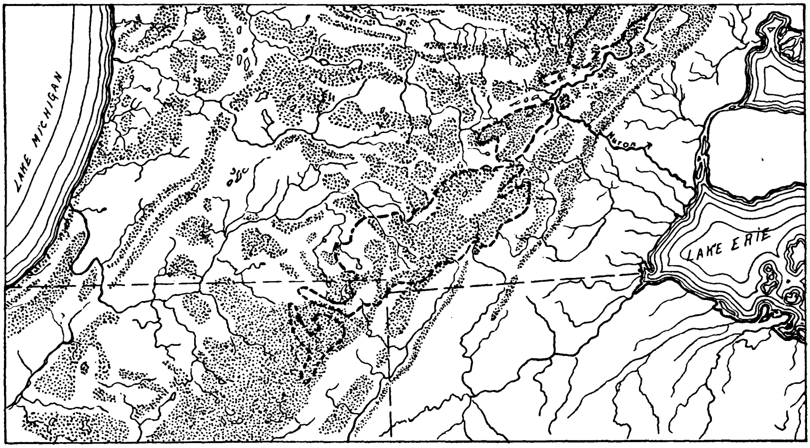


FIG. 2.—Map of southern Michigan, northern Indiana, and northern Ohio, showing "moraines with strong expression." After LEVERETT, U. S. Geol. Surv. Mon. 41, *plate 2*. The irregular dotted lines mark the 1000-foot (300^m) contour.

The waters from the glacial drainage at first flowed generally westward, reaching the Kalamazoo River near Albion, thence to the St. Joseph at Three Rivers. At South Bend, Indiana, it crossed to the Kankakee River, and reached the Mississippi by way of the Illinois.

---

[2] For general map see no. **55**, p. 411. (Bibliography at close of this paper.)

As the reentrant extended itself further to the northeast, another channel was opened for the Huron drainage westward past Pinckney into the Grand River, and from there to Battle Creek and the Kalamazoo River. Below the city of Kalamazoo it cut across to the Paw Paw River, and reached the Mississippi by way of Lake Chicago.

When the ice of the Erie lobe had retreated as far eastward as Ann Arbor, and all of the interlobate moraine had been uncovered, a third outlet for the waters of the Huron was opened by way of Clinton and the Raisin River, which at that time emptied into glacial Lake Maumee at Adrian (**32**, *pl. 20*). This lake was drained by the Wabash River into the Mississippi.

As soon as the ice margin passed the clay morainic belt already described, the Huron reached Lake Maumee at Ypsilanti by way of its present channel. But Lake Maumee had meanwhile changed its outlet to the northward, its drainage going by way of Imlay (**53**) to the Grand River, Lake Chicago, and the Mississippi (**32**, *pls. 21, 23, 26*).

Later the Erie basin was entirely freed of ice, and its water for the first time flowed eastward into the Ontario basin (glacial Lake Iroquois), and thence by way of the Mohawk to the Hudson. With the clearing of the St. Lawrence channel the present system was inaugurated.

Aside from the physiographic interest connected with their early history, these glacial drainage channels are of distinct biological interest. They furnish continuous lowland habitats extending in all directions. In so far as they are represented by broad, open valleys, and connect with tributaries of the northern Ohio valley, they provide important highways for the dispersal of southern river-valley species.

FORESTS.

The three topographic divisions already described exhibit marked differences in their forest aspect. On the lake plain we find the richest and most mesophytic of the forest types. This lowland habitat is a continuation of the northern Wabash valley, and it is not surprising that its flora should be of much the same character. Here we find the greatest variety of tree species, among which are *Fagus atropurpureus*, *Quercus rubra*, *Ulmus americana*, *Platanus occidentalis*, *Acer saccharum*, *Tilia americana*, *Acer saccharinum*, *Fraxinus americana*, *Gleditsia triacanthos*, *Liriodendron tulipifera*, *Gymnocladus dioica*, *Cercis canadensis*, *Asimina triloba*, and *Celtis occidentalis*.

The clay morainic area is dominated by *Quercus rubra*, *Q. alba*, *Q. velutina*, *Hicoria ovata*, *H. glabra*, *Acer rubrum*, *Ulmus americana*, and *Quercus macrocarpa*.

In the region of the interlobate moraine the disappearance of the more mesophytic forms is quite marked. The forest is there largely composed of *Quercus coccinea*, *Q. macrocarpa*, *Q. velutina*, *Q. alba;* and as we go northeastward these become associated with *Pinus strobus*. *Quercus prinoides* forms a characteristic shrubby growth along the roadsides and in waste places.

Such is the forest background in which are set the thousands of acres of bog and swamp, and to which the groves of *Larix laricina* exhibit a marked contrast. These tamarack areas are to be seen on all sides in the region of the interlobate moraine; they are quite common in the clay morainic belt, but are practically wanting on the lake plain.

As one follows along the morainic country from northern Indiana into the "thumb"of Michigan, he passes from a region dominated by a rich mesophytic broad-leaved forest to one of conifer and xerophytic broad-leaved ascendency; from a region whose low grounds are characterized by a swamp flora to one in whose depressions the bog flora reaches a high state of development. In this connection it is interesting to note that one finds this gradual change epitomized in the Huron valley as he goes from its mouth to its source.

METEOROLOGICAL CONDITIONS.

Under this head we shall consider the general meteorological conditions of the Huron basin, and compare them with the meteorological conditions found about the center of the distribution of bog plants (**55**, p. 406). In general, this center extends from Lake Winnipeg through the upper Great Lake region down the valley of the St. Lawrence to the Atlantic coast. It is in the coast provinces, however, that the bogs reach their highest development, in the form of the "raised bog." Certain temperature phenomena associated with the bog habitat will be discussed in connection with the analysis of the life conditions obtaining in bogs.

Rainfall.—In the following table is given the mean monthly and annual precipitation for seven stations located within or near the Huron basin. As their individual variation is but small, it is probable that the average for the stations gives a fair estimate of the rainfall and its distribution. Appended are the corresponding records for the maritime region of eastern Canada:

MEAN PRECIPITATION IN INCHES.

Station	Alt. feet a.t.	Record for Yrs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Ann Arbor.	930	23	1.99	2.19	2.12	2.88	3.72	3.39	2.82	2.45	2.58	2.82	2.77	2.35	32.08
Ypsilanti. .	736	18	1.97	2.61	2.48	2.24	3.98	4.02	3.09	2.24	2.63	2.70	3.29	2.32	33.60
Jackson. . .	927	6	2.06	2.21	3.14	1.26	3.22	3.02	2.47	1.76	1.74	3.61	2.87	1.56	28.92
Annpere. . .	924	11	1.98	2.19	2.42	2.60	3.38	2.44	2.66	2.85	1.93	2.04	2.64	1.77	26.05
Ball Mt. . . .	932	13	1.73	1.76	2.07	2.12	3.52	3.13	2.47	2.59	2.62	2.69	2.71	2.30	29.72
Birm'gham	860	15	1.91	2.00	2.32	2.53	3.36	3.15	2.56	2.38	2.33	2.51	3.02	1.88	29.95
Average.			1.94	2.16	2.42	2.27	3.53	3.19	2.68	2.38	2.30	2.73	2.88	2.03	30.22
St. John, N. B.(18)		?	5.55	3.93	3.80	2.50	3.66	2.72	3.29	4.64	3.08	4.13	4.71	5.16	47.17
Halifax, N. S.(51)		22	5.63	4.94	5.15	4.00	4.43	3.68	3.43	3.96	3.53	5.21	5.26	5.52	57.74

It will be noticed from the above data that the precipitation is quite evenly distributed throughout the year. It reaches its maximum during the months of May and June, when the vegetative processes of the bog plants are most active. It approaches its summer minimum during July and August, when the temperature commonly attains its greatest height. The former implies that the water level in the bogs is kept at or above the surface of the substratum for weeks at a time. The latter involves strong transpiration on the part of the vegetation, when the water supply must be drawn for the most part from the substratum. The average number of rainy days during the past five years is one hundred per annum.

The average snowfall in this region during the five years, 1898 to 1902, amounts to 38.4 inches (975 ^{mm}). In the case of the bogs this thickness is usually increased by the drifting of snow from the surrounding hills. Observations during the past two winters show that the bogs are covered by ice to a thickness of a foot (30 ^{cm}) or more.

Consequently, low shrubs, and herbs which pass the winter by means of underground stems, are well protected from low temperatures and sudden temperature changes. The ice further results in lowering the temperature in spring and in retarding the beginning of favorable growth conditions.

The percentage of sunshine is not published by the several stations, but the number of clear and partly cloudy days is stated. The numbers from the various stations show marked differences, due to different standards established by the observers; but perhaps these are largely eliminated in the average. If we take the average number of clear days, add to it one-half the number of partly cloudy days, and divide by the number of days in a year, we obtain a percentage of forty-six. This probably approximates the percentage of sunshine.

In comparison with the rainfall data for Halifax and St. John, it is notable that in the latter localities the mean rainfall, both monthly and annual, is considerably larger. The annual precipitation exceeds that of the Huron valley by fully 20 inches (50^{cm}), or about 40 per cent. Finally, the sunshine percentage is slightly lower, being 39 for Halifax and 42 for St. John.

Temperature.—The following table exhibits the monthly and annual means for the several stations already cited:

MEAN TEMPERATURE IN °F.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Ann Arbor..........	22.2	23.1	30.6	45.4	53.2	67.3	72.0	69.3	62.5	49.9	36.4	27.1	46.6
Ypsilanti............	25.9	24.2	32.3	46.7	58.1	63.5	71.1	69.7	61.8	49.9	36.7	27.6	47.3
Jackson.............	26.1	20.3	32.7	47.5	59.4	69.4	74.8	71.8	64.8	54.7	37.7	26.5	48.8
Annpere............	24.7	21.7	31.3	50.2	56.5	68.4	71.8	67.6	63.0	49.8	35.9	26.7	47.4
Ball Mt.............	22.6	21.4	27.6	45.3	56.0	66.9	70.0	68.1	62.2	49.5	35.9	27.1	46.0
Birmingham.........	23.1	22.8	30.4	46.5	57.3	69.1	72.2	68.4	61.5	49.7	36.7	27.0	47.1
Average...........	24.1	22.2	30.8	46.9	56.7	67.1	71.9	69.1	62.6	50.6	36.5	27.0	47.2
St. John, N. B.......	18.6	18.7	26.3	38.6	48.8	56.3	61.0	61.3	55.6	44.7	36.1	23.7	40.8
Halifax, N. S........	22.0	22.7	28.7	38.2	48.7	57.6	64.2	64.8	58.2	48.0	38.2	27.0	43.2

The table shows that the temperature conditions are comparatively uniform throughout the basin. The maximum average temperatures occur in July and August. But the significance of the data becomes more apparent, in so far as the bog vegetation is concerned, when they are compared with those of St. John and Halifax (*fig. 3*). It is to be noted that, although the average temperature for June, July, and August of the Huron basin is 8.6° F. (4.8° C.) higher, its rainfall during the same period is less by 2.6 inches (66 ^{mm}). There can be little doubt as to the effect of such differences upon the growth of the bog species, especially the sphagnum whose moisture supply is more directly dependent upon atmospheric water than upon the soil solution. Again, the occurrence of high temperature with decreased precipitation means the production of conditions impossible for the development of the "raised bog," if not unfavorable to the highest development of the "flat bog."

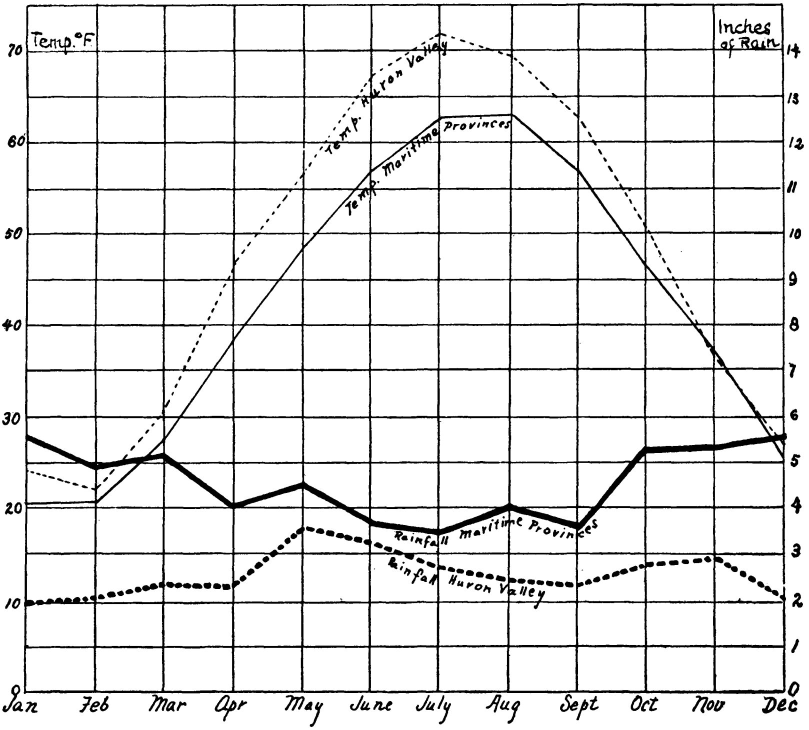


FIG. 3.—Curves of rainfall and temperature conditions in the Huron basin compared with those of the maritime region of Canada.

Since bogs attain their maximum development in a region of great rainfall and comparatively low temperatures, it is reasonable to infer that the extremes of summer heat become peculiarly significant in this region. Examination of the weather records shows that temperatures of 97–100° F. (36–38° C.) are likely to occur every year, and that temperatures approximating these may be prevalent for several days in succession each season. When these extremes coincide with periods of drought, they must act as important checks on the growth of the bog plants, especially the sphagnum. As we pass from northern Indiana along the moraine into Michigan, the gradual increase of bog development, of the variety of bog species, and of the areas covered by sphagnum is very marked. Although other factors are involved, this increase may be correlated with a decrease in summer temperature extremes.

II. The bogs: their development and ecological conditions.

PHYSIOGRAPHIC ORIGIN OF THE LAKE AND BOG BASINS.

In connection with the special consideration of the bog flora, it is of interest to note the origin of the depressions in which this flora has developed and flourished. Indeed, in the morainic belt of the Huron basin it would seem that among the agencies which have produced important topographic changes since glacial times, the bog plants stand near the head of the list. Stream erosion and deposition have been slight, while lake basins have been filled and the level of depressions generally raised by the deposition of plant débris.

As no attempt has as yet been made at the mapping of peat deposits and muck soils, no reliable estimate of the total amount of aggradation accomplished by plant agencies can be made. Yet the frequency with which in field work one encounters peat soils, in various stages of making or decay, suggests that in the aggregate such deposition has been most effective in this region. The northwest quarter of the Ann Arbor topographic map, which embraces an area of about 215 square miles (55,700 hectares), located in the morainic portion of this basin, indicates approximately 43 square miles (11,500 hectares)—20 per cent.—as swamp land. It is probable that at an early time this area was very much larger, but with the settlement of the land many extensive areas have been drained and only the dark humous soil remains to suggest its past history.

The most frequent source of lake and bog basins is here found in connection with the deposits made by glacial drainage. Among the vicissitudes attending the retreat of a glacier are the occasional detachment of blocks and masses of ice through differential melting (**19**). If these detached masses happened to be in the line of the overloaded glacial drainage, they became covered to a greater or less extent by sand and gravel. Owing to the poor conduction of heat by such deposits, they melted with extreme slowness. Where this latter process was prolonged until the drainage line had been abandoned or the stream had ceased depositing, subsequent melting brought about a settling of the deposits and the production of basins. Sister, Kavanaugh, and Crooked Lakes are examples of this type.

In the case of the chain of lakes which form a part of the Huron River in northwestern Washtenaw County, and such lakes as Portage, Tamarack, Ore, and Bass, according to LEVERETT, there was an additional settling of the fluvio-glacial deposit itself. This latter process has been of the greatest importance in the development of extensive bog areas. In the Portage Lake region this settling has amounted to as much as 40 feet (12^{m}) in certain places, and has resulted in reducing many hundreds of acres of land to the ground water level.

Throughout the belt of till plains occur shallow marshes, sometimes drained, but usually by a sluggish meandering stream, itself impeded by the growth of swamp plants. These basins are the natural expression of the unequal deposition of glacial material. Till plains result from a comparatively rapid retreat of the ice; hence the depressions are usually shallow, and have been mostly filled with peat to the level of the present drainage. The several small lakes lying to the west of Dexter are examples of basins not yet obliterated.

Where the retreat of the glacier is slow and deposits are made to a great thickness about the edge of the ice, kame or "knob and kettle" topography results. The basins of such areas are characterized usually by high margins and comparatively steep slopes. West, Silver, North, Island, and South Lakes may be cited as examples.

As we know from remains discovered in peat deposits, among the animals inhabiting this region in early postglacial times were the mammoth, mastodon, bison, peccary (*Platygonus compressus* LeConte) (**57**), elk, and "big beaver" (*Castoroides ohioensis* Foster). The last named is not a beaver (**34**, p. 256), but is more nearly related to the Coypu rat of South America. The common beaver

(*Castor canadensis* Kuhl) has been an important factor in the creation of bog areas (**37**), and in the extension of areas already existing, by the building of dams. The beaver was found in this section when it was first settled, but the last known specimen was killed sixty-nine years ago. The occurrence of peat deposits several feet in thickness and covering quite large areas, bordering streams, whose channels lie deeply sunken in the deposits, seems to find its best explanation in this manner. But little field work has been done on the relation of beavers to the peat deposits, and examples are still too hypothetical to cite in this connection.

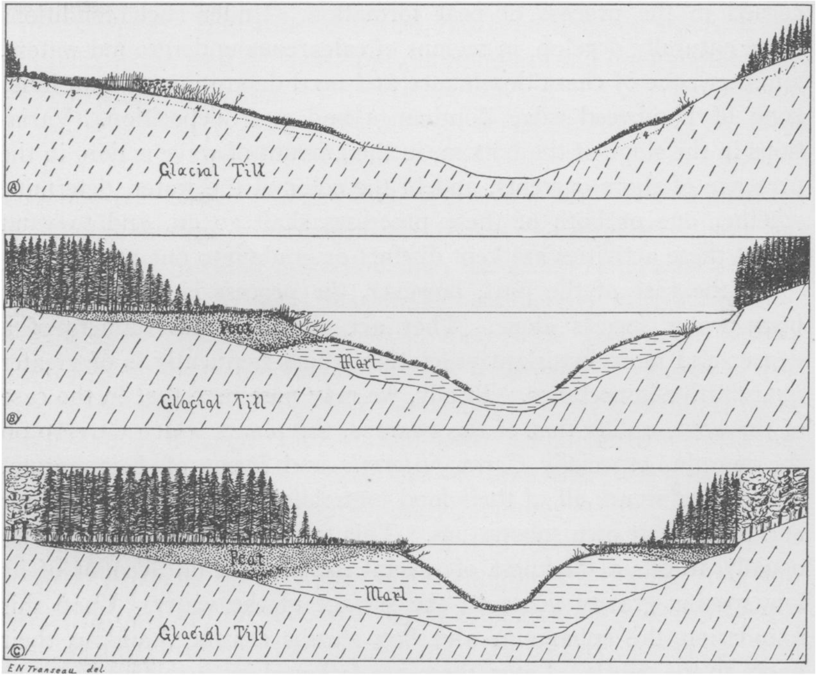
BOG AND LAKE VEGETATION.

Of the plants which might come into a new land area containing basins, such as was laid bare on the retreat of the glaciers, none is better adapted to rapid migration than the group of aquatic plants. Whether we have in mind the smaller submerged varieties or the partially submerged littoral species, their wide geographic distribution and uniform associations bespeak their evident solution of the problems of dispersal. The fact that deposits of peat and marl have been found in northern Indiana and lower Michigan to a thickness of 40 feet (12^{m}) would indicate that in these particular basins the vegetation must have obtained an early foothold.

Concerning the deposition of marl, it is of interest to us only in so far as it becomes an agent of aggradation in the basins. In the reports (**5, 42, 21**) on the marl deposits of Indiana and Michigan, many examples are cited where the marl forms the underlying substratum of peat deposits. That its deposition to a large extent is due to plant life has been shown by DAVIS (**9, 10**). The plants most concerned with this process are the Characeae and Cyanophyceae (Schizothrix, Zonotrichia). They are probably aided by certain mollusks, and perhaps also by chemical precipitation. As for the Characeae and Cyanophyceae, they have a wide range of habitat in different lakes, and may occur in deep or shallow water and on various rock substrata. Where they come into competition with shore species, the rank growth of the latter usually precludes their existence in sufficient amount to be of importance in marl formation. Where wave action is strong, the chara is confined to deeper water, but the blue-green algae may be present up to the water's edge, in such situations frequently forming marl pebbles. The lower limit of existence is largely determined by the transparency of the water, and may lie between 20 and 30 feet ($6-9^m$). Of the littoral plant associations there are commonly two quite distinct divisions, the outer made up largely of submerged or floating pondweeds and water-lilies, the inner of half-submerged rushes and sedges. Both are concerned in the process of peat formation. Under such conditions there naturally develop, in regions of calcareous underground waters, an outer zone of chara dominance and marl deposition, and an inner zone of pondweed-sedge dominance and peat deposition. Variations in the slope of the bottom, in the amount of wave action, in the presence of shore currents, and in the color of the water, determine whether one or both of these processes shall go on, and to what extent these activities are kept distinct or grade into one another.

In the case of the peat, however, the process is not dependent upon water species alone. They act merely as forerunners of a denser and more luxuriant vegetation which frequently is of greater quantitative importance. Briefly, we may note here that in the case of the bogs, unlike that of the swamps, the plants which develop on the margin, especially *Carex filiformis* and forms of Friophorum, are able to secure all of their food materials from the water and air and build their own substratum. This tangle of roots and rhizomes usually attains a thickness of several inches, and on account of its low specific gravity floats on the surface of the water. Upon this foundation the sphagnum and bog shrubs advance, adding their quota to the débris. Later, these are followed by such tree forms as the tamarack. Coincident with this increased weight and augmented rate of deposition, comes the progressive submergence of the floating substratum, and its gradual disintegration and humification. The accompanying *fig. 4* will serve to illustrate this process.

Within the last two years much has been promised toward the utilization of the peat deposits in this region for fuel purposes. Companies have been organized, and the machinery necessary for the drying and consolidating of the peat has been much improved. At Capac and Chelsea, factories have been erected, and attempts are being made to place the industry on an economic basis. If these ventures prove successful, we may hope for an interesting body of scientific information to come from the study of bog sections. The work of ANDERSON, LAGERHEIM, SERNANDER, WEBER, and others in Sweden and Germany, gives indication of the data concerning postglacial migrations of plants and animals, and climatic changes, which will be obtainable when our bog deposits become of economic importance.



E N Transeau del.

FIG. 4.—Diagrams illustrating three stages in the development of peat and mar deposits in lake basins. In drawing the figures it has been assumed that the rates of marl and peat deposition are approximately equal. The peat accumulates most rapidly on the western side of the basin. On the east side a common effect of wave action is illustrated. The process of peat formation is hindered, while that of marl deposition goes on until the aggradation of the bottom reduces the force of the waves sufficiently to allow the bog plants a foothold. *A* represents conditions in early postglacial times when these basins acquired their first flora. The several plant societies represented are (1) conifer (2) bog shrub, (3) bog sedge, (4) aquatic, the outermost division of which is the chara association. In *B* the conditions for the growth of plants belonging to the northeastern conifer forest formation have reached their optimum. *C* represents present conditions in southern Michigan. The plants belonging to the southeastern broad-leaved forest formation, being climatically favored, occupy the areas of mineral soils, while the conifers are almost restricted to bog areas.

THE GEOGRAPHIC DISTRIBUTION OF PEAT DEPOSITS.

In North America the distribution of recent peat deposits may be conveniently summarized under two heads, genetically unrelated: (1) those of glaciated regions; (2) those of the coastal plain.

The peat of the glaciated area constitutes the great bulk of these American deposits. The southern boundary of this region is marked by a line passing westward from central New Jersey through northern Pennsylvania and Ohio, central Indiana and Illinois, thence northward through southern Wisconsin, northwestward to the Minnesota valley and the Red River of the North in Manitoba, westward through northern Assiniboia and southern Alberta to the Rockies. Here the boundary is deflected southward into Montana, but in crossing toward the coast it is again carried northward into British Columbia, and finally southward among the Cascades of Washington to the Pacific Ocean.

Along this southern border the peat deposits are exceedingly scattered and make up a small fraction of the total land surface. They have accumulated under water in depressions among the recessional moraines. As we go northward, the relative proportion of peat bogs and peat deposits regularly increases, and there is a notable tendency toward the accumulation of pure humus in situations other than depressions containing water. When the tundra or "barren ground" is reached, the accumulation of humus is almost universal. The contrast with our own region is well brought out in RUSSELL'S account of the tundra (**43**, p. 129). The vegetation

> grows rapidly during the long, hot, summer days, dies below and partially decays, but becomes frozen and has its complete destruction arrested, while the dense mat of roots and stems continues to thrive. In this way an accumulation of partially decayed vegetable matter is formed, which increases in thickness from year to year by additions to its surface. The process is similar to that by which peat bogs are formed in temperate latitudes, except that the partially decomposed vegetation becomes solidly frozen. It is in reality an example of cold storage on a grand scale.
>
> Under existing climatic conditions there does not seem to be any limit to the depth such deposits may attain. The amount of carbonaceous material already accumulated in the tundras of America and Asia must equal that of the most extensive coal field known.

South of the boundary above described, peat deposits of considerable extent are occasionally met with. In the region of the great plains they are sometimes found beneath a surface covering of sand and wind-blown deposits. TODD (**54**, p. 121) has mentioned the occurrence of such peat deposits in eastern South Dakota. BARBOUR also reports such deposits from central and eastern Nebraska (**2**). On the basis of their field relations and certain fossils which they contain, they are believed to be of Glacial and early Pleistocene age. If the plant materials of these deposits could be carefully worked over with reference to their successive floras, we might hope for some new light on glacial climate, since a part of the deposits are beyond the margin of the Wisconsin ice sheet. But even their location and existence give evidence of climatic change, and plant and animal migration. Although now widely separated from the region of active bog formation, they are historically connected with this division.

Among the mountains of both the eastern and western United States, bogs and swamps are to be found in association with mountain lakes. More frequently than otherwise these depressions are connected with former local glaciation, perhaps the most frequent situations being those afforded by the damming back of water by terminal and lateral moraines. Basins for peat accumulation are also found in solid rock made by glacial erosion. The conditions here are quite similar to those of the north, the altitude bringing about the same general effect as the latitude. The analogy is still further shown on mountains in moist regions where alpine meadows are strongly developed. Not only are the plants related to those of the tundra, but the deposition of peat or humus is again irrespective of basins.

In many places east of the great plains there is another type of situation not directly connected with glaciation, but in which vegetable débris may accumulate to considerable thickness, viz., about the débouchure of cold springs. Toward the north these springs may bring about humus accumulation on slopes, but further south peat is usually associated with pools and small lakes.

The second group of situations in which peat accumulation takes place on a grand scale, are those associated with coastal plain phenomena, such as the rising and sinking of the land, the irregular deposition of alluvial materials in deltas, and the extension of the land through reef building. These swamps have been described by SHALER, KEARNEY, JULIEN, and others (**46, 26, 24, 7**). They reach their greatest development in eastern Virginia, North Carolina, Florida, and the Mississippi floodplain. They may contain either salt or fresh water, and their vegetation is noted for its density and luxuriance.

The geographical distribution of peat deposits is of interest in this connection because it points to certain factors which contribute to the preservation of humus materials. Certainly in arctic latitudes the most significant factor is the low temperature, for humus accumulates to great thickness even with a scant vegetation. In the northern states and southern provinces of Canada, peat is associated with basins containing stagnant water or cold springs. The annual increment from the vegetation is greatly increased over that of the tundra. Mild temperatures and stagnant waters combine to preserve the plant débris. When we come to the coastal plain swamps of the southern states, this process takes place only where a luxuriant vegetation is combined with areas of stagnant water of considerable depth.

To put it sharply, we may say that, in spite of the scant vegetation, the cold of the tundra results in peat accumulation. In temperate latitudes, mild temperatures and stagnant water combine to prevent the complete disintegration of a vigorous vegetation. In the south, in spite of the high temperature, the luxuriance of the vegetation and stagnant water unite to make peat formation possible.

THE PROCESSES INVOLVED IN PEAT FORMATION.

When for any reason the living protoplasm in a plant or any of its organs is brought to the condition of death rigor, the continuance of this state for a prolonged period inaugurates certain chemical and physical processes which result in the breaking down of the exceedingly complex structures and compounds making up the living plasma. Among the first outward signs of such disorganization is the loss of water. The cells of soft tissues lose their normal form, and in any case the tissue becomes more or less filled with gases. The protoplasts as such disappear, and in their place granular carbohydrate and proteid bodies are to be found.

Aside from the mineral substances composing the ash of such bodies, the organic compounds are made up for the most part of carbon, hydrogen, and oxygen. In the case of the proteids, there are added to these nitrogen, sulfur, and phosphorus. As to the exact nature of the compounds existing in the dead material, aside from the carbohydrates, very little is known. The same statement holds as to the nature of the decomposition which goes on without the intervention of saprophytic organisms. But it seems probable that oxidation does occur. This action, then, is the beginning of the more comprehensive process known as peat formation.

When plants or their organs die, under ordinary circumstances they are at once attacked by fungi and bacteria. The progress of dissolution is then greatly hastened, and the final disintegration is more complete. According to the operation of certain external factors, the destruction may involve two very different groups of organisms and result in bodies of very different chemical and physical properties. These two processes are known as eremacausis and putrefaction (**61, 39**).

Where access to oxygen is accompanied by favorable temperature and moisture conditions, the first of these processes, eremacausis, takes place. The formation of ordinary soil humus may be cited as an example. That oxygen plays the important rôle has been demonstrated both by experiment, and by the analysis of the gaseous and solid products. It has been shown, for example, that soils in which eremacausis is in progress contain CO_2 and O in inverse proportion to one another. Under constant volume, as the one increases the other decreases. It has been also shown by experiment that the process is wholly dependent upon the activities of certain lower plants. Among these members of the genera Mucor, Aspergillus, Penicillium, Saccharomyces, Micrococcus, Bacterium, Spirillum, Crenothrix, and Beggiatoa are most important.

The carbohydrates are by this means broken down to CO_2 and H_2O. The albuminoids and amides constitute the principal forms of the nitrogenous materials. Under the influence of these organisms, especially their katabolic processes, the oxygen unites with the carbon to form CO_2, the S is oxidized to H_2SO_4, the P to H_3PO_4, and the H to H_2O. The first form in which the nitrogen reappears is that of ammonia. This is at once attacked by the nitrifying bacteria, and changed successively to the form of a nitrite and a nitrate. The two latter changes again involve the addition of oxygen.

If we consider only the temperatures occurring in nature, we may say that these activities increase regularly with the temperature. As to water conditions, it has been shown that in air-dry soil eremacausis is practically wanting, and that when the soil is filled with water it is reduced to a minimum. Between these two extremes lies an optimum at which there is sufficient moisture for the life of the organisms, and yet not enough to interfere with the diffusion of oxygen. An acid condition impedes, and a slight alkalinity favors, the production of both the carbon and the nitrogen compounds.

Eremacausis is then essentially a process of oxidation, brought about by lower organisms, whose activities are favored by a high temperature, a slightly alkaline medium, and free access to the air. Its products are simple compounds which may furnish food materials for the higher plants living on the substratum in which they are formed.

By putrefaction is meant that process of disintegration which occurs when organic matter decays in the absence of oxygen. Here again organisms are involved, but they belong for the most part to the anaerobes, and are wholly forms of bacteria. The process is essentially one of reduction.

Carbon dioxid is again the principal gaseous product, but its relative amount is greatly reduced. Along with it CH_4, H, H_2S, H_3P, N_2O, and N are produced in small quantities. In the manufacture of the carbon dioxid the oxygen is not only derived from the organic matter, but also from nitrous oxid, nitrites and nitrates which may be present. In the decomposition of cellulose, carbon dioxid and methane result from the hydrolysis of the cellulose molecule. Albumins at first break up into amido-acids, nitrogenous compounds of the aromatic series, and other little-known bodies. If the decomposition continues, the amido-acids in turn form ammonia and compounds of the fatty-acid series. The latter substances may still further disintegrate to carbon dioxid, hydrogen, and methane. Depending upon the stage in the progress of decomposition, we may find complex organic compounds, organic acids, and their salts, or comparatively simple substances.

As to the influence of external factors, high temperatures increase the rate of disintegration, while the presence of acids prevents its continuance, due to the killing of the bacteria involved. It is to be noted that the products of putrefaction, both intermediate and final, can be of little use in furnishing food materials for the higher plants.

With these two processes in mind, we may now consider the matter of peat formation as it occurs in this region. We have already seen how the substratum is being extended at the edge and renewed at the surface by the plants forming the outer zone of the bog vegetation. It consists of sedges, especially forms of Carex and Eriophorum. Each year these plants send up stems and leaves from the matted rhizomes. At the approach of winter these are killed, and the snow later on aids in bringing them down to the water level. In the spring the water covers almost the whole of this zone to the depth of several inches. With the gradual lowering of the water level and the coming of warmer temperatures, the conditions for eremacausis are made favorable. If the water is approximately neutral in its chemical reaction, the fungi and bacteria begin the work of disintegration, which if continued would result in the complete destruction of the vegetable débris. However, on account of the great demand for oxygen, the process can be carried on only near the surface of the water. Even at a depth of a few centimeters the rate of oxygen diffusion is so small, as compared with the demand for it, that practically all aerobic bacterial action is prevented. All of the surface waters which I have examined have been found to be teeming with bacteria.

Close upon the extension of the bog-sedge zone comes the sphagnum-heath zone. Here the surface is characterized by hollows and elevations, the latter frequently due to the upward growth of the sphagnum beneath the shade of the heath plants, but in some cases due to the building of mounds by ants. In the hollows the water stands above the substratum throughout a large part of the year and even during dry periods lies just at the surface. Unlike the sedges, the principal plants of this zone are evergreen. The sphagnum forms a continuous mat of living plants several centimeters in thickness, through which all of the oxygen must diffuse before it can be available for the eremacausis of the dead plant-material beneath. The cassandra, cranberry, and andromeda which compose the bulk of the shrubby vegetation add to the débris largely by their leaves and underground stems. The former fall to the substratum as they die, but not at the close of each vegetative period. Consequently they are soon lost among the sphagnum, and there is no distinct annual layer added.

But beneath this layer of possible aerobic activity, the material would seem to be subject to putrefactive agencies. And there can be no doubt that such destructive processes are carried on in those situations in which the acidity of the soil solution does not preclude the existence of the anaerobic bacteria.

Among the taller shrubs and trees, such as *Vaccinium corymbosum*, *Aronia nigra*, and *Larix laricina*, the defoliation takes place each autumn. As these plants are of relatively large size, the bulk of the material forms a noteworthy annual addition to the substratum. When to this is added the twigs and small branches which fall each season, we can understand the fact that the substratum is almost entirely free of surface water. Usually the ground-water level lies 5–10 ^{cm} below. But the substratum has a high water-capacity and is kept constantly moist. Where the sphagnum covering is wanting for one reason or another, the dark color of the surface peat shows how much more complete is its disintegration as compared with that of the other zones. This condition is made possible by its position relative to the ground water. On the other hand, as will be shown later, the temperature conditions are more favorable in the zones of herbaceous and shrubby vegetation.

Most of the basins in which peat formation is going on actively, are subject to considerable variation in water level, both seasonal and annual. During the last two years the rainfall has been considerably above the normal in lower Michigan, and many of these bog areas were flooded. At West Lake, for example, a large part of the tamarack area was covered with water to a height of several inches above the level of the roots. Most of the basins are also subject to higher water level in the spring and during prolonged rainy periods. Accompanying such changes there are great differences in the rate and manner of decay. High water, in so far as it excludes oxygen, favors putrefaction; if it comes as a result of heavy rains, it decreases the acidity of the soil solution, increases its oxygen content, and at least for a short time favors the growth of the saprophytes causing eremacausis. Low water level exposes a much greater bulk of the substratum to disintegration, and favors the carrying away of the products of decomposition; in general, it favors eremacausis. In the samples of water which I have examined at various times from the same depressions, there have been marked variations within short periods of time in the color of the water and in the presence of such animals as Daphnia and Cyclops. No attempt has been made to count or even separate the bacteria present, but it is probable that they too vary with the color of the water and the animal life.

When the bog land has been cleared and ditched, the marked increase in the rate of decay is apparent. Eremacausis becomes exceedingly active, and in the course of a few years the substratum is reduced to a brownish-black, pulp-like mass. If continued, this goes to form "muck," a substance which when dry is powdery and somewhat resembles soot. During these processes of decay there occurs a succession among the organisms present. The accumulation of disintegration products makes the medium unfavorable for the continued existence of the organism involved in their production. At the same time it may furnish optimum conditions for the development of other forms. An acid medium favors the growth of the Phycomycetes, while alkalinity favors the bacteria. In such regions as this, where the underground waters are alkaline, the latter fact, together with fluctuations in the ground-water level, may have an important bearing upon the presence of more thoroughly decayed peat and of a distinct depression about the margins of many of the bogs.

If to the factors of relative scarcity of oxygen and the acidity of the soil solution is added the occurrence of temperatures considerably lower than those of the surrounding uplands, it is not difficult to understand why a large part of each year's vegetative products should escape complete destruction. In our estimate of the bog substratum as a habitat for higher plants, the strong competition with the microscopic plants to which the former are subject in the acquisition of oxygen for their underground parts, must be emphasized.

THE PHYSICAL AND CHEMICAL PROPERTIES OF PEAT.

The peat formed through the agency of the bog sedges and their attendant plants has a fibrous and matted appearance. The structures of the various dead stems, roots, and leaves have suffered but slight alteration. They were originally strongly cuticularized, and this has aided in their preservation. The color is commonly a pale yellowish-brown. During life these plant materials become strongly matted and interwoven, and this structure frequently persists. It is this structure that gives to the Carex-Eriophorum zone in many lakes its strength to support heavy bodies. A man's weight will carry the substratum a foot beneath the surface of the water, but it seldom breaks under the strain. In the case of lakes where this zone is unusually developed, it may cover a large part of the lake surface and be of great importance in the filling in of peat. In such cases the deposition takes place largely by the gradual falling of material from the under side of the floating substratum. On account of the slight weight of the material, it does not descend and produce a compact deposit on the bottom, but forms a sort of thick liquid peat.

The sphagnum-shrub zone, where well developed, usually shows a brown peat beneath it. It is composed largely of sphagnum and the semi-decayed twigs, rhizomes, and leaves of the other plants. It is distinctly fibrous, but of a type different from that of the sedge zone; the fibers are short, and the material is not nearly so tenacious.

Under the tamaracks a large part of the annual peat increment is made up of the tamarack needles, though mosses (Hypnum, Sphagnum, and Polytrichum) usually are of importance in this connection. The color is reddish-brown and darker than that of the shrubby zone. The fibrous structure is still less apparent, though present.

When these bogs have been burned over and partially drained, there frequently comes in a dense ground covering of moss (Polytrichum). In such cases the peat continues to accumulate, largely through the agency of this plant. In such situations the peat is a reddish-brown, and the plant structures have practically disappeared through decay. Below the upper layer, the peat when moist has the sticky, clayey properties of well-decomposed peat.

One other well-marked stage is shown in the areas of muck land now under cultivation to onions and celery. Under the influence of drainage and tillage, the disintegration is nearly complete. All plant structures have disappeared, the humous acids have been largely neutralized or washed out, and there is left only a fine, powdery, brownish-black "muck."

The following table shows some other physical properties of these several varieties of peat.

	Eriophorum Zone Peat	Fresh Sphagnum	Cassandra-Sphagnum Zone Peat	Tamarack Zone Peat	Chelsea Bog Peat	Onion Marsh Muck
H_2O-capacity % by volume.......	87.0	78.0*	91.0	84.0	82.0	75.0
H_2O-capacity % by weight........	892.0	1550.0	960.0	530.0	477.0	283.0
Air dry H_2O-content %..........	8.5	10.6	10.0	10.0	10.0	10.0

*Low volume percentage due to air present in tissues.

These measurements were made by placing the peat samples in a zinc cylinder of 600^{cc} capacity. The bottom of the cylinder was closed with a wire gauze cap. The moist peat was tamped into the cylinders with as nearly uniform a stroke as possible. The cylinders were then set in a dish of water for eighteen hours, after which the cylinder was removed and allowed to drip. When all dripping had ceased, the cylinder was weighed. The peat was then removed and allowed to dry at room temperature, and again weighed. Finally it was dried at 110° C., and the absolute weight determined. As usual in such measurements, considerable irregularity was shown by the different samples, owing to the difficulty of removing the air, and of packing to the same degree. However, the figures bring out clearly the fact that sphagnum more than any other plant influences the water-capacity of a peat containing it. The eriophorum peat has a lower capacity, owing to its coarse fibrous structure. Of the series examined, the highest water-capacity was found in the cassandra zone. The effect of further decay and destruction of the plant tissue is shown by the reduction in water-capacity of the last three members of the series. The percentages are of interest in connection with the utilization of such lands for agricultural purposes, in showing the difficulty of proper drainage. It is the experience of the men who ditch these bogs that until the peat has reached the condition termed "muck" the ditches act only with extreme slowness.

Chemically, peat or humus is made up of varying quantities of several substances of a rather indefinite character, which are commonly classified among the dehydration products of the carbohydrates. These bodies not only occur in nature, but may be artificially produced by the action of strong acids on starch, sugar, and cellulose. The relation of nitrogen to these bodies is still unknown. Principally on the basis of color and solubility in alkalies and acids, there are several substances distinguished. Ulmin and ulmic acid are brown, and are early products of decomposition. Humin and humic acid are black, and occur more abundantly where eremacausis has been active for a long time. Crenic and apocrenic acids appear to be further oxidation products; the former is colorless, and the latter varies from yellow to brown. MAYER believes these bodies to be organic nitrogen compounds (**36**), and on this basis STOCKBRIDGE (**50**, p. 135) explains the insolubility of peat soils and the presence of the unavailable nitrogen in peat. Beside these substances xylic, saccharic, and glucinic acids have been recognized. Although great advances have been made in soil chemics, it seems strange that the only suggestion of formulæ for these substances was made by MULDER in 1861 (**38**).

Humic acid forms water-soluble compounds with the alkalies, and to these are due largely the brown colors of the bog waters. The color may be produced by the presence of free humic acid. With the alkaline earths humic acid forms insoluble or difficultly soluble compounds. Hence there is slight chance of lime and magnesia penetrating from the surrounding soil into the peat deposits.

During the changes which the plant material undergoes in the process of peat-making there are alterations in the relative amounts of volatile hydrocarbons, fixed carbon, and ash—using these terms as in ordinary coal analyses.

	Eriophorum Stems and Leaves	Sphagnum	Eriophorum Zone Peat	Cassandra Zone Peat	Tamarack Zone Peat	Onion Marsh Muck
Volatile combustible	68.2	67.0	62.0	54.0	53.0	45.7
Fixed carbon.......	21.0	17.9	21.8	22.9	23.4	21.8
Ash...............	3.8	4.5	7.4	13.8	13.6	22.5
H_2O..............	7.0	10.6	8.8	9.3	10.0	10.0

The proportion of volatile combustible matter decreases regularly as the humification proceeds. The ash regularly increases, while the air-dry water content shows but slight modification.

(*To be continued.*)